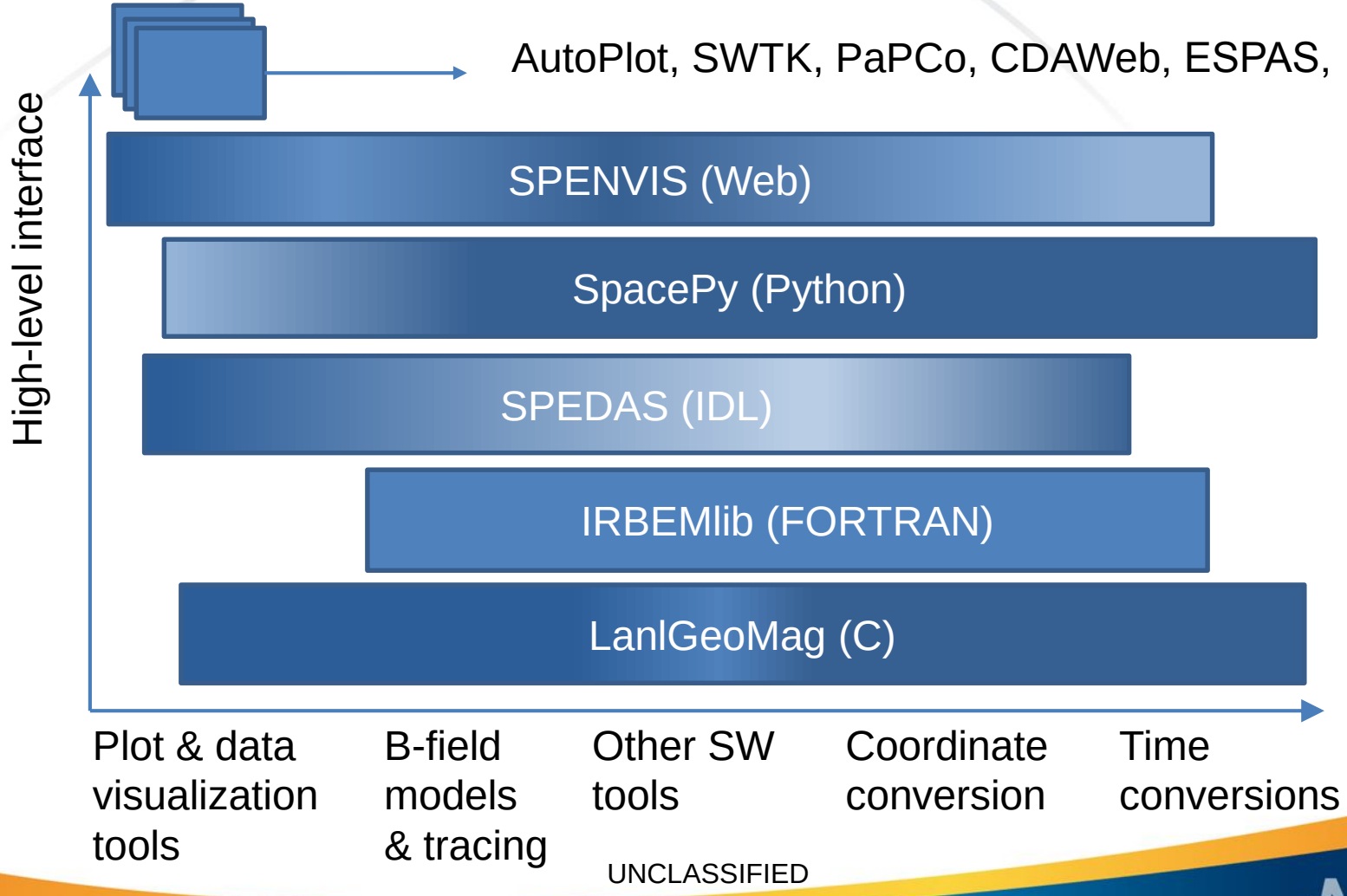
SpacePy and LanlGeoMag

Software libraries for space science data analysis, modelling and space weather forecasting

SpacePy team: Steve Morley; Brian Larsen; Dan Welling; Jon Niehof
LanlGeoMag team: Mike Henderson; Steve Morley; Brian Larsen; Jon Niehof

Intended Audience

What are they for?



Why Open Source?

Rationale for SpacePy and LanlGeoMag

- Free software
  - No licence required
  - Widely used programming languages
- Source code available under version control
  - No “black box” routines
  - Bug trackers, feature requests, quick feedback
- Common routines available to whole community
  - Work is reproducible
- Good for scripted jobs
  - LGM is threadsafe and re-entrant, uses OpenMP
  - Python has easy multi-processing capabilities

Models Included

An Incomplete Selection

SpacePy

- B-field models from IRBEM library
- AE-8/AP-8 (IRBEM)
- Plasmapause
  - Carpenter & Anderson
  - Moldwin et al.
- Magnetopause standoff
- L* neural network
- 1-D RB diffusion model
  - Ensemble Kalman filter

LanlGeoMag

- CDip; EDip; IGRF; Chen & Schulz; Jenson-Cain
- T87; T89c; T96; TSK03; T02; TS04; TS07
- Olsen-Pfitzer
  - Static; Dynamic
- Simplified Mead
- NRLMSISE-00
- B from scattered mesh
- AE8/AP-8

Tools Included

An Incomplete Selection

SpacePy

- Tracing
  - Field lines; Drift shells
- Superposed epoch analysis
  - 1D; 2D
- Bootstrap CI
- Association analysis
- Windowing mean (time based, points based)
- Time & Coordinate conversions

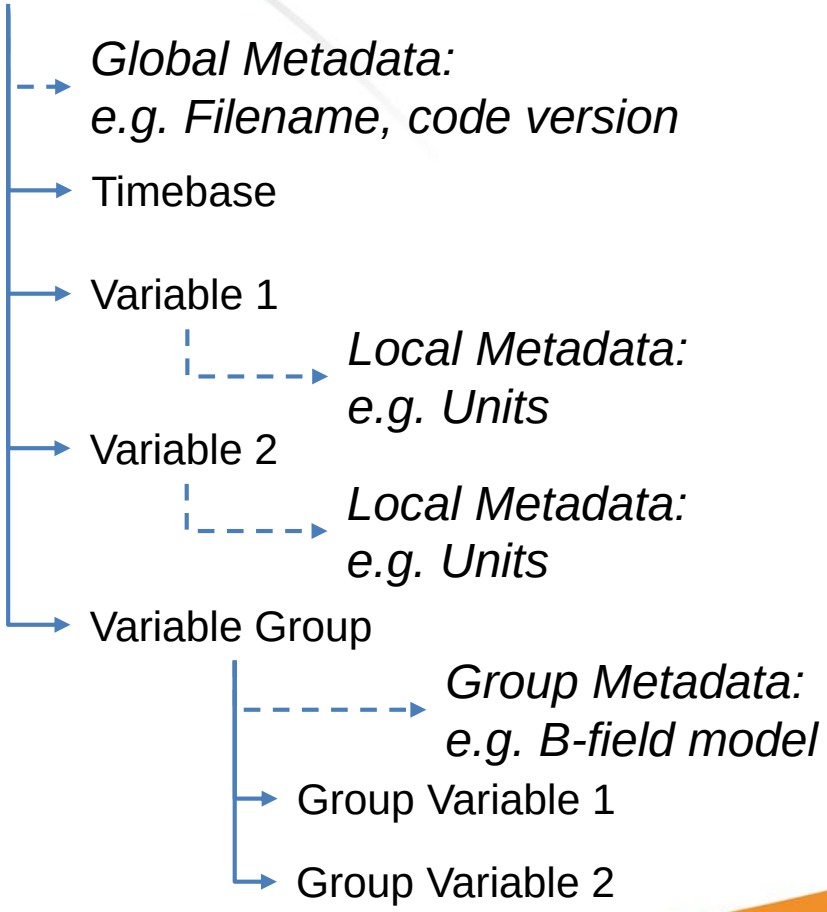
LanlGeoMag

- Tracing
  - Field lines; Drift shells
- Octree; k-D Tree
- SGP4 orbit propagator
- PSD(μ,K) calculation
- Diffusion coefficents
  - Bounce-averaging in arbitrary fields
- Quaternion operations
- Time & Coordinate conversions

A Data Model

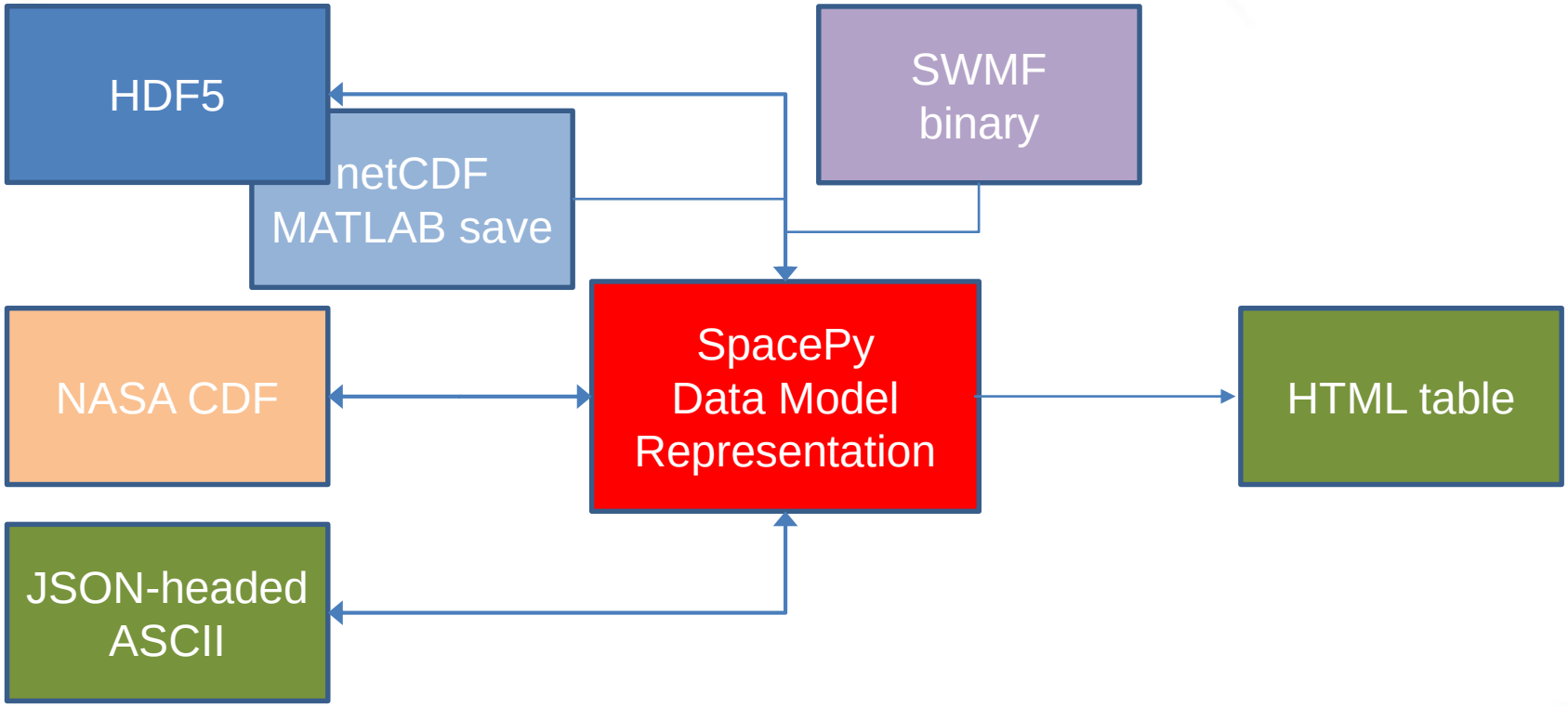
Similar to HDF5 Model

- Two basic datatypes:
  - Group
  - Dataset
- Both have metadata
- Groups can contain groups or datasets
- Datasets are array-like
- Supports many metadata standards



File Types

Conversion via a common data model



JSON-headers

Carrying metadata in ASCII data files

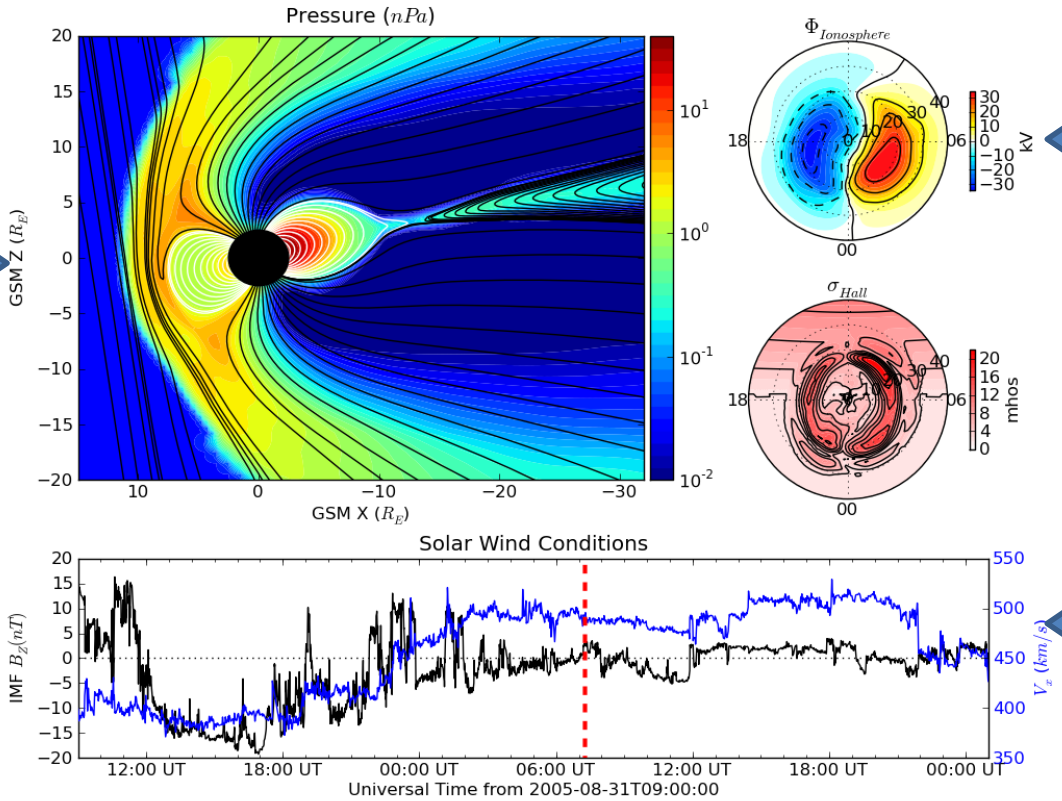
```
#  "Pmin_gsm":   { "DESCRIPTION": "Location of minimum-|B| point (in GSM coords).",
#                        "NAME": "Pmin_gsm",
#                       "TITLE": "Minimum-|B| point (in GSM Coordinates)",
#                       "LABEL": "T01S Pmin_gsm (R!BE)",
#                       "UNITS": "R!BE!N",
#                   "DIMENSION": [ 3 ],
#                "START_COLUMN": 100,
#               "ELEMENT_NAMES": [ "Pmin_gsm_x", "Pmin_gsm_y", “Pmin_gsm_z" ],
#               ELEMENT_LABELS": [ "T01S Pmin_gsm!Bx!N , R!BE", "T01S
↳Pmin_gsm!By!N , R!BE", "T01S Pmin_gsm!Bz!N , R!BE" ],
#                  "FILL_VALUE": -1e31 }
```

In use: PyBATS

Space Weather Modeling Framework

BATS-R-US output

Tracing done in SpacePy



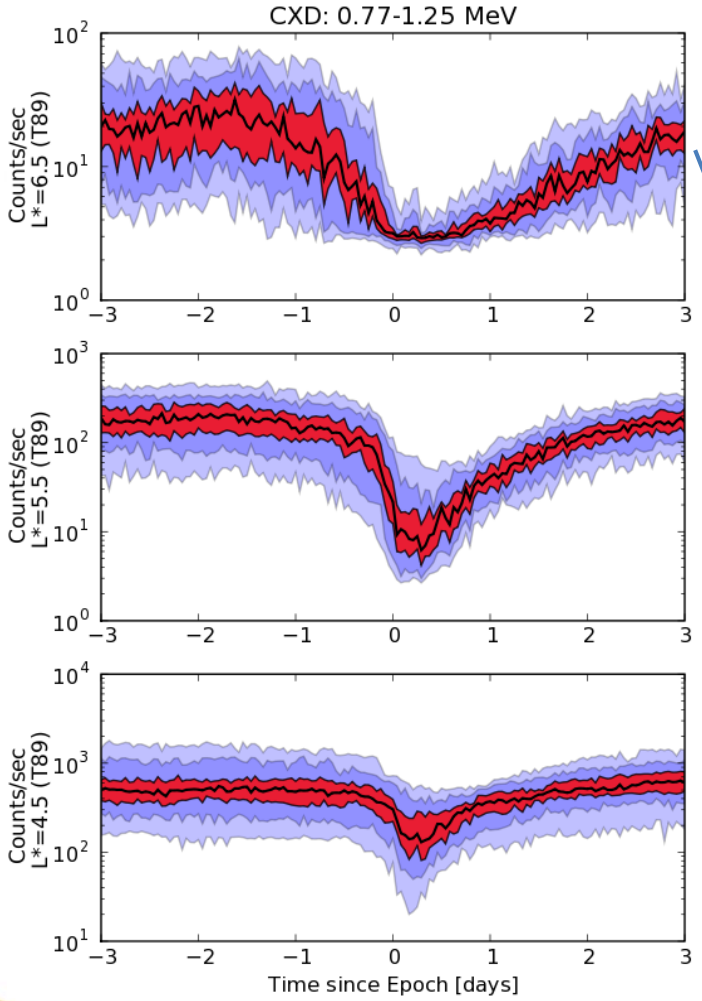
Ionospheric Electro-dynamics (IE) module

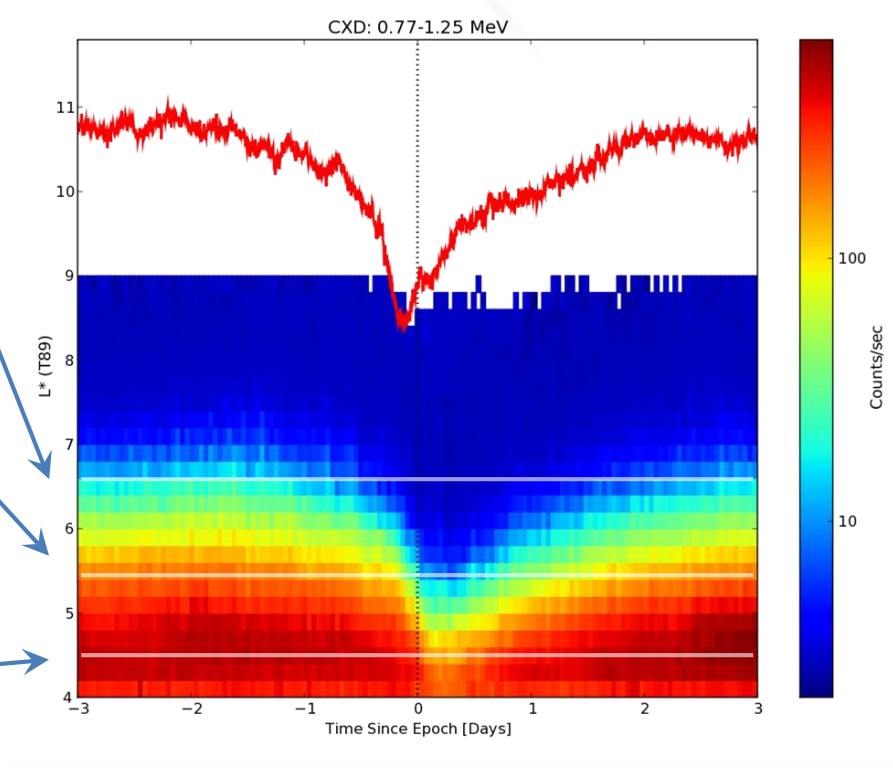
Solar wind data through SpacePy OMNI module

UNCLASSIFIED

In Use: SeaPy

Analysis of GPS particle data





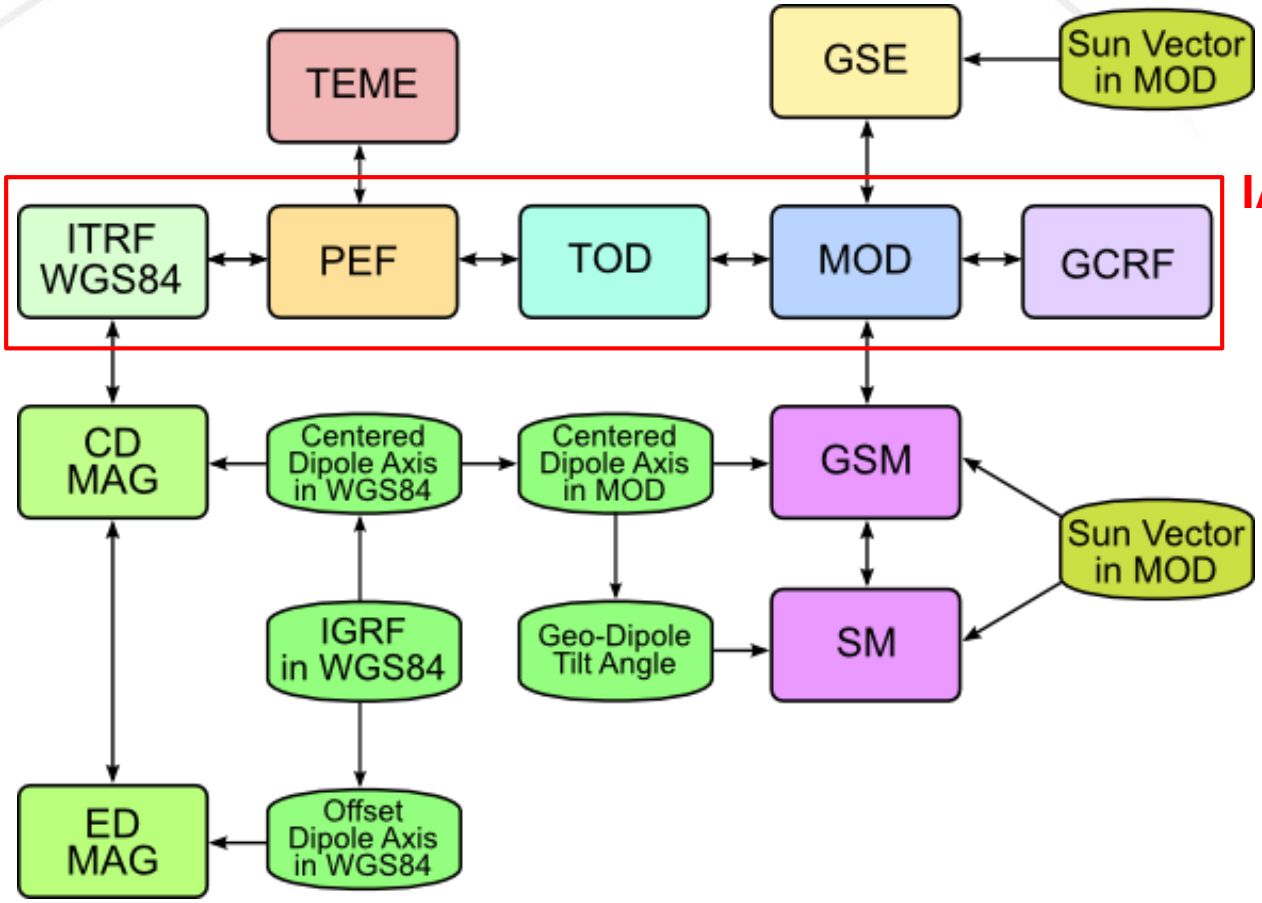
Morley et al., Proc. Roy. Soc. A, 2010

UNCLASSIFIED

LanlGeoMag

Coordinate Systems and Transformations

ITRF and WGS84 are same to within ~cm

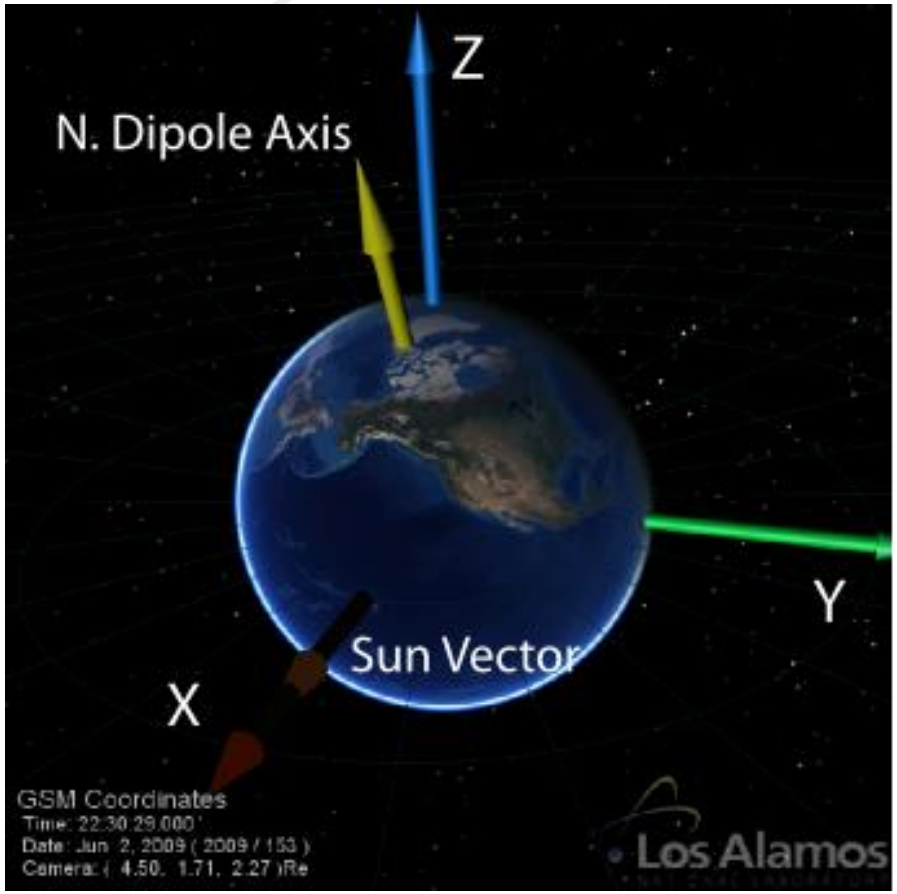


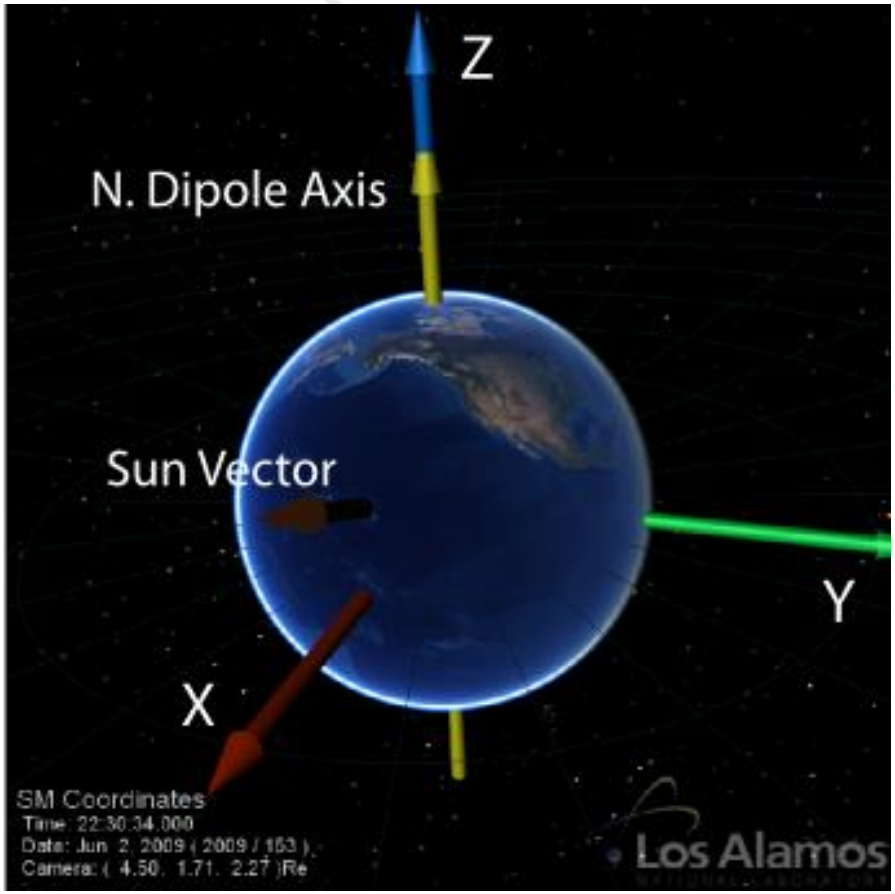
IAU-76/FK5

GCRF and ECI(J2000) are same within uncertainty of FK5.

ViewDriftShell: 3D visualizer

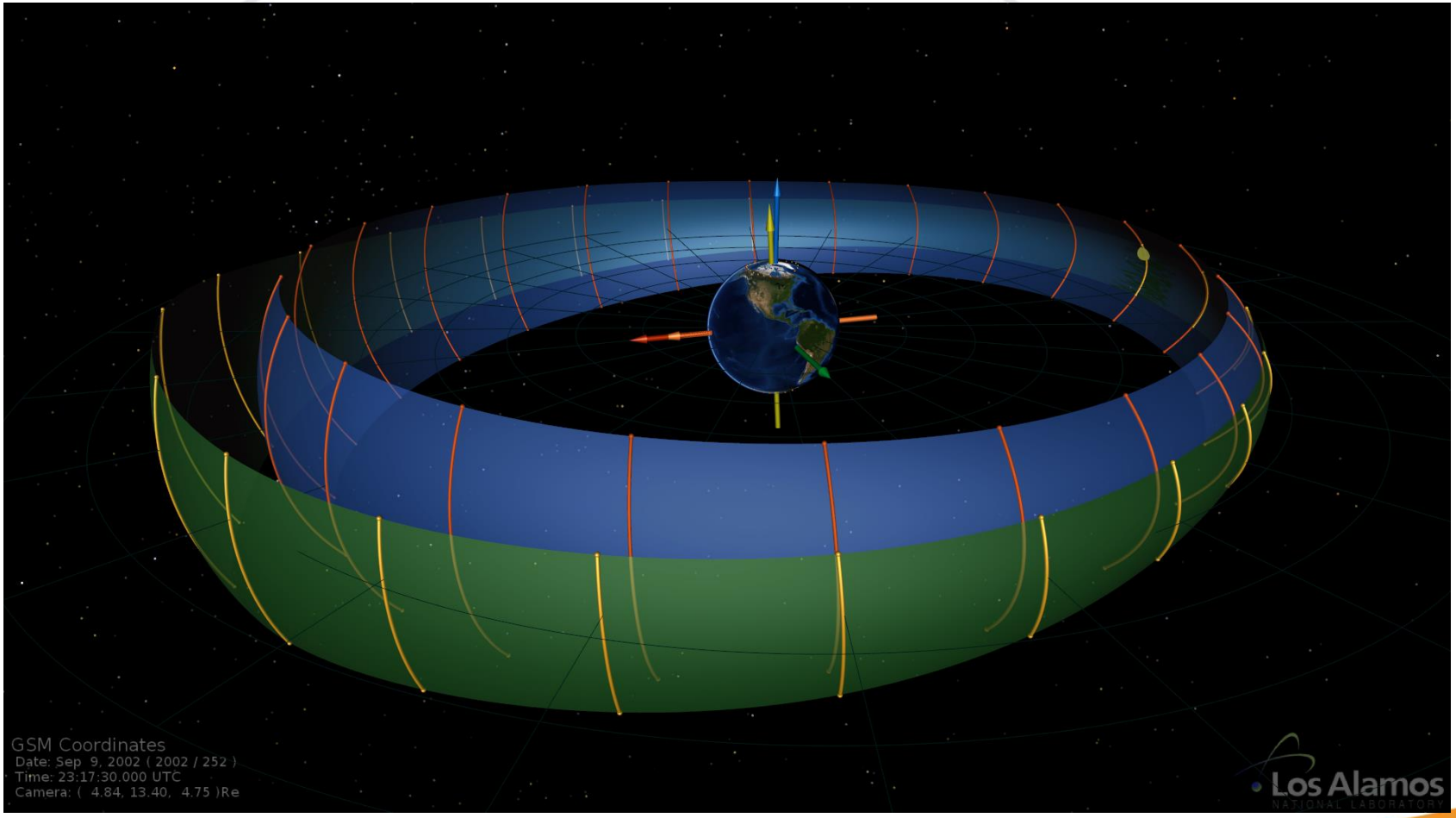
Multiple Coordinate Systems





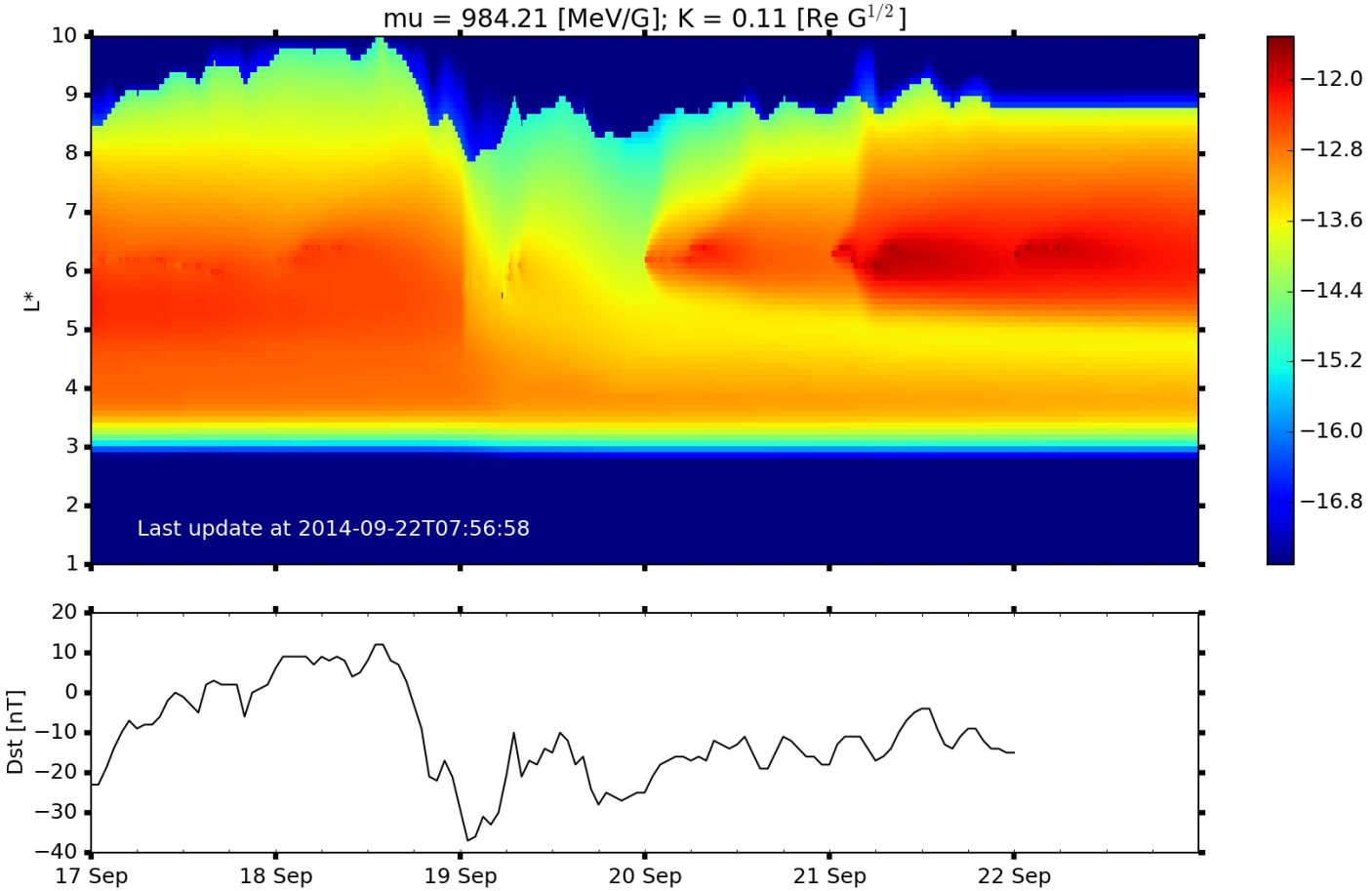
ViewDriftShell: 3D Visualizer

Visualizing Drift Shells



In use: Real-time DREAM

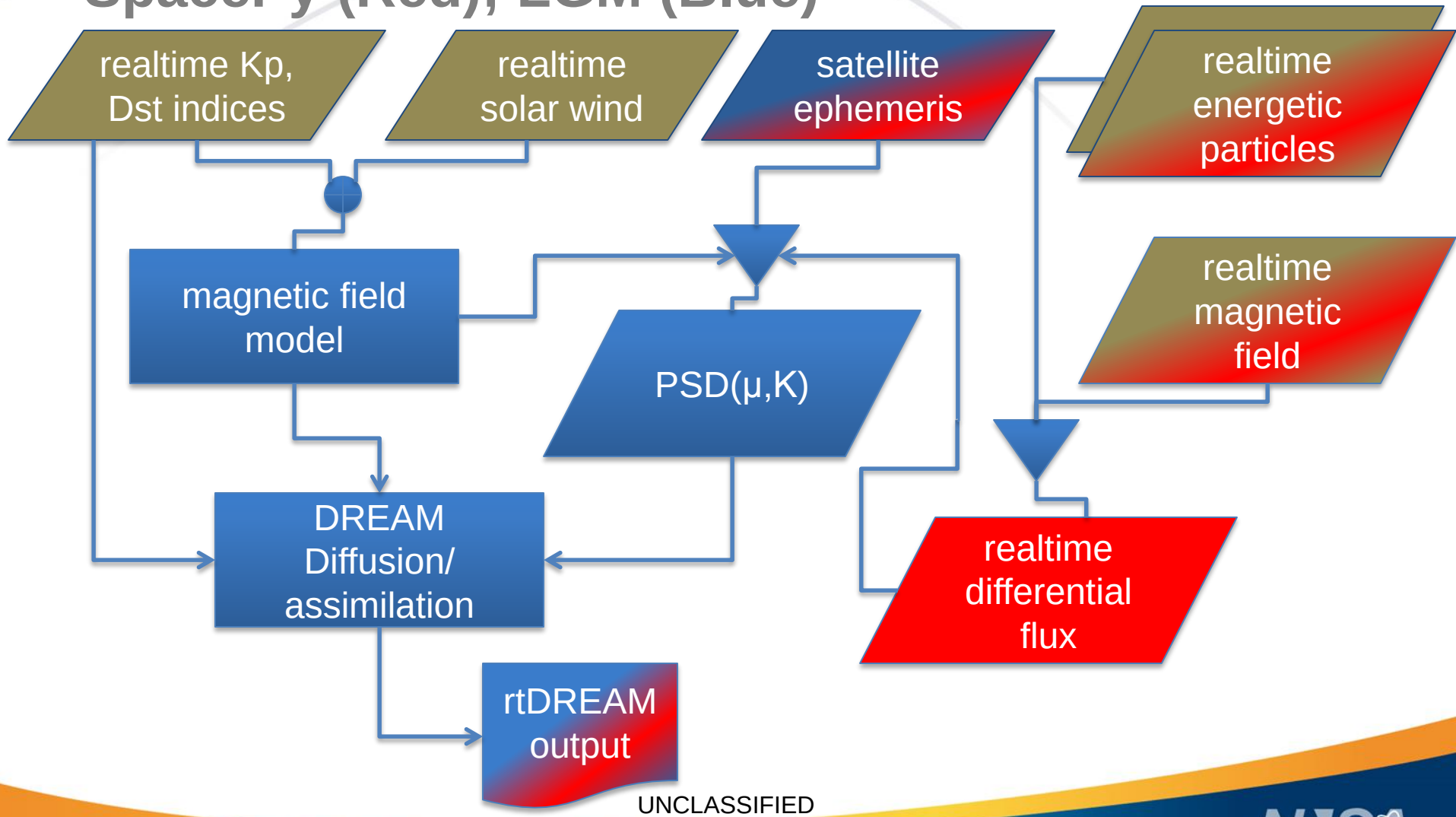
Radiation Belt Nowcasting



UNCLASSIFIED

Data Flow: Real-time DREAM

SpacePy (Red); LGM (Blue)



UNCLASSIFIED

In use: Magnetic Ephemeris

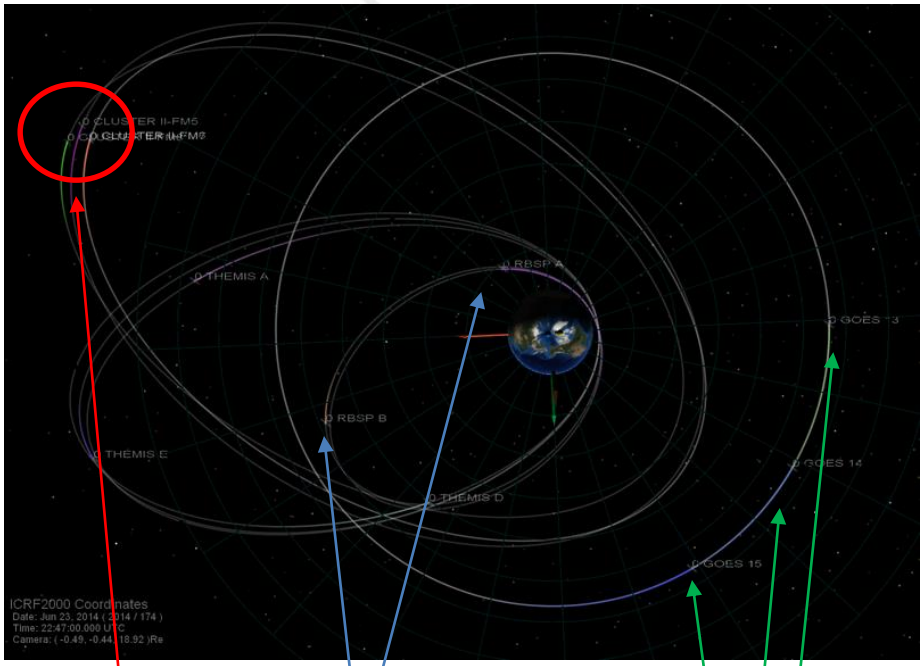
Van Allen Probes, MMS, GPS

Position, Attitude, e.g.

- GEI_{J2000}, WGS84
- GSE, GSM, SM

Field Quantities, e.g.

- $\vec{B}$, B/B_0, FL length & type
- $I(\alpha)$, $L^*(\alpha)$, $L_m(\alpha)$
- $\kappa(E)$ *[adiabaticity parameter]*
  - *(Min. radius of curvature) /(maximum gyroradius)*
- Footpoint locations



RBSP-A, RBSP-B

Cluster

GOES

Where to get code and help…

And what's coming next?

- SpacePy (current v0.1.4; new release imminent)
  - Code repository (git) on SourceForge
    sourceforge.net/projects/spacepy
  - Online documentation
    spacepy.lanl.gov
- LanlGeoMag (currently no official release cycle)
  - Code repository (git) on GitHub
    github.com/drSteve/LANLGeoMag
  - Documentation in repository

LanlGeoMag interface in SpacePy is under development